R&D Focus of DLR in the field of CSP

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DLR HELMHOLTZ

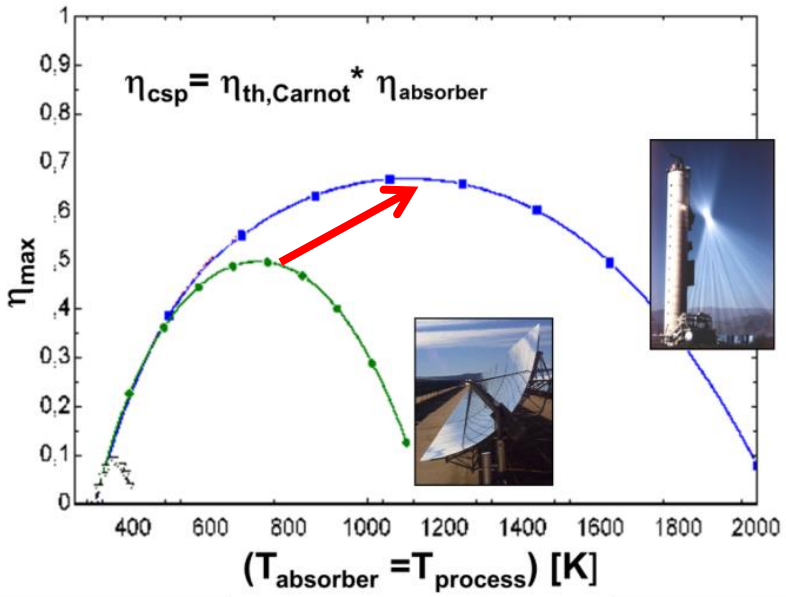
Outline

Research Focus 1: New heat transfer fluids to break temperature limits

Research Focus 2: Impact of desert environment on CSP performance and life-time

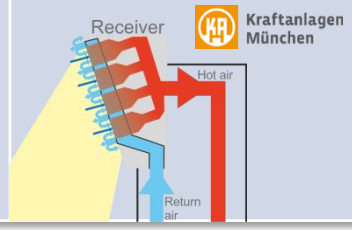
Research Focus 3: Real Size Condition Monitoring of CSP Power plants

Challenges and Objectives



- High Concentration + High Temperature = High Efficiency = Low Cost
- Advanced heat transfer media needed for:
  - High temperature operation
  - Efficient storage integration

→ Break todays temperature limit of 400°C (trough) / 560°C (tower)

Silicon Oil	Air	Advanced Salt	Particles	Liquid Metal
T_{max} = 480°C	T_{max} > 700°C	T_{max} > 600°C	T_{max} > 900°C	T_{max} > 800°C
				

Third party funding | Risk | Helmholtz Funding

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Research Question 1

Can ceramic particles be used as efficient heat transfer media at T >650°C to achieve η_{sys} >20%?

- CentRec® system concept and performance modelling
- Particle flow: theory, model, experiments
- Design of 500 kW receiver
- First results from 500 kW receiver test

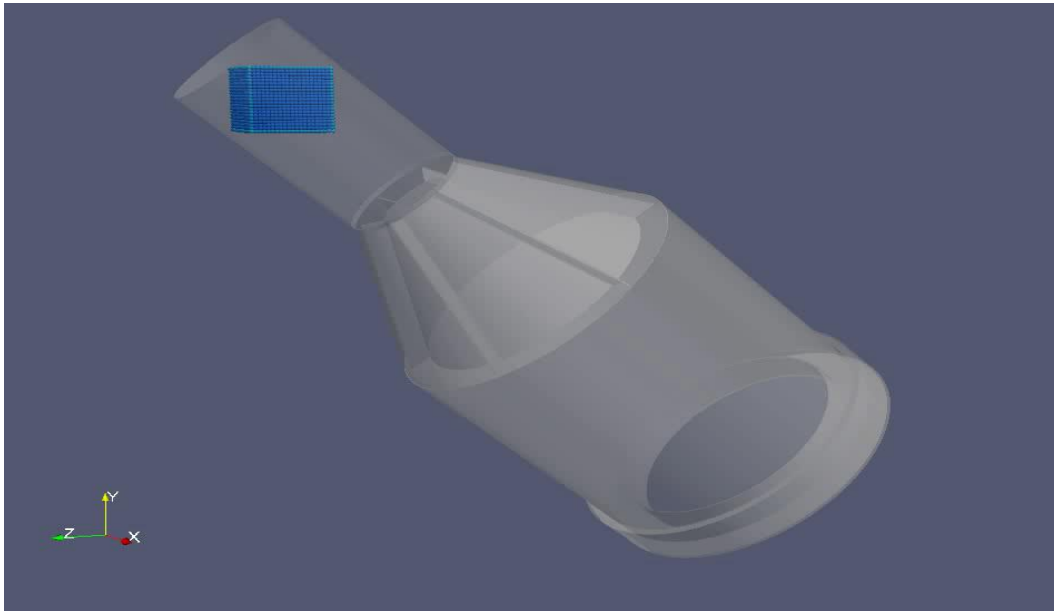
Infrastructure:
Solar receiver test platform
@Juelich Solar Power Tower

Result: Concept of Particle Receiver

Bauxite particles

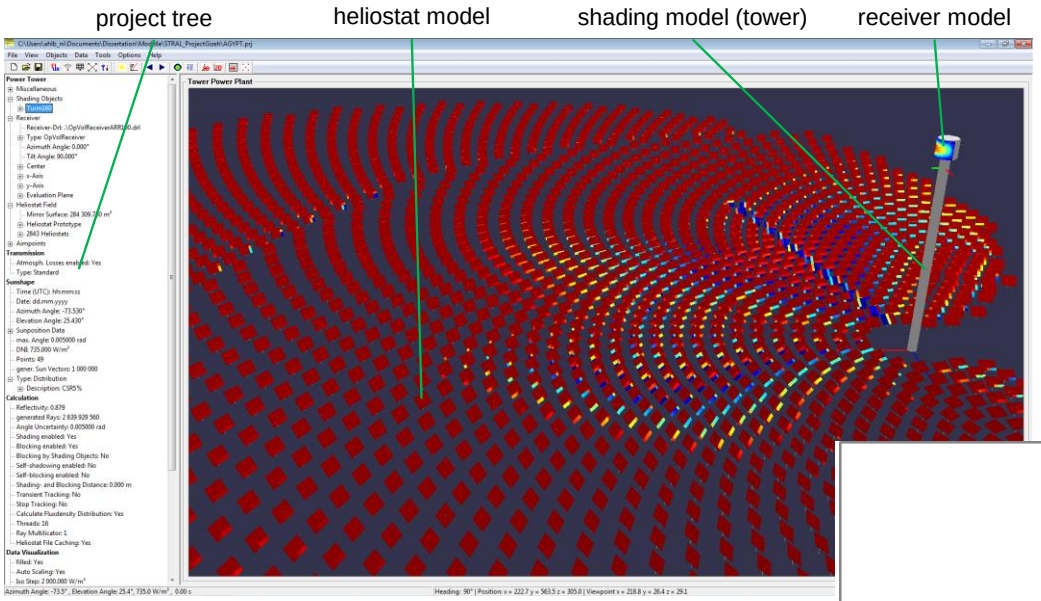
- Cheap (500 – 1000 €/t)
- Stable >1000°C
- Direct absorption
- Direct storage
- Low cost to move

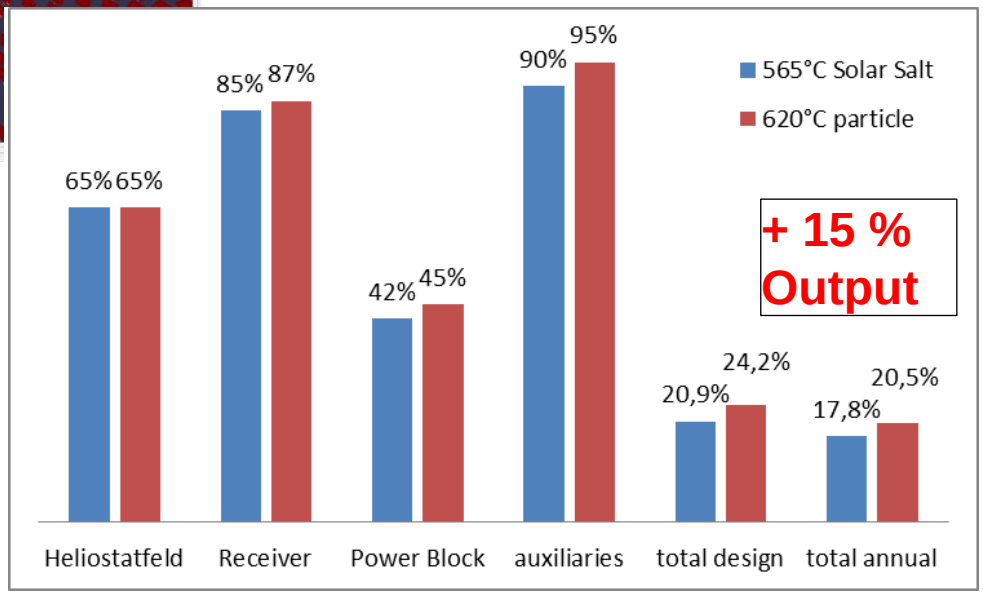
CentRec® rotating receiver concept



- Residence time controlled by rotational speed
- Cylinder walls isolated by particle layer

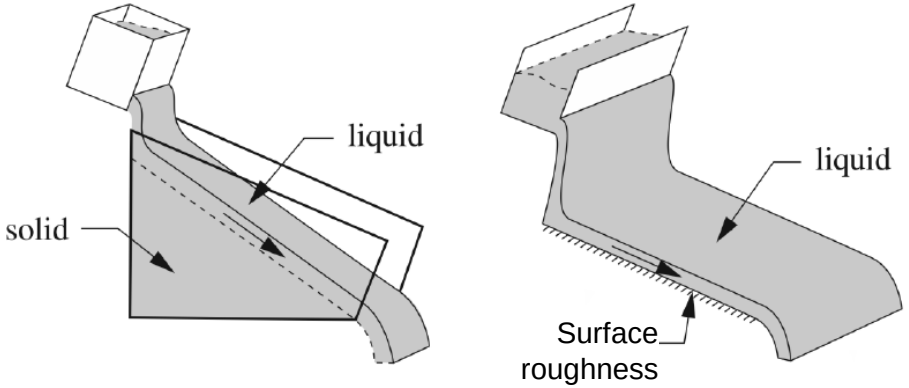
Results: Particle Receiver – detailed modelling



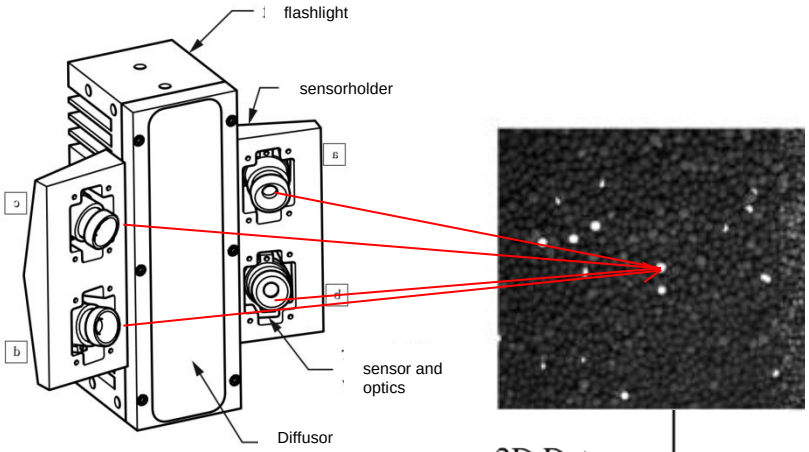


Results: How to achieve Homogeneous Particle Flow

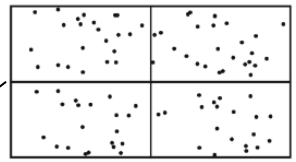
- One- or two-phase flow depending on layer thickness
- Avalanches below critical mass flow
- Flow characteristics depend on
  - Mass flow,
  - Surface roughness,
  - Particle diameter and roughness
  - Inclination angle
- No models available in literature to predict flow conditions



Results:
Rotating Camera System for Particle Tracing Velocimetry

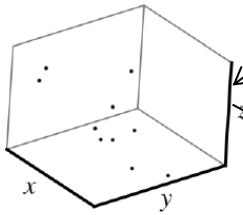


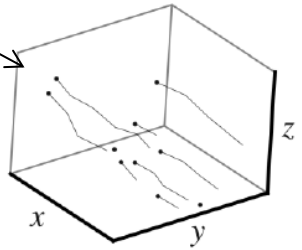
2D Daten



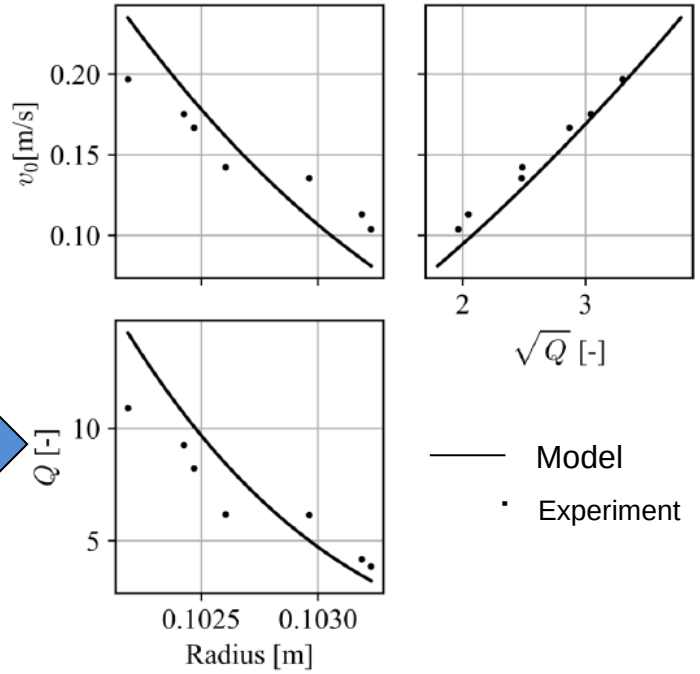
Tracks

3D Daten





Measurement data used to validate particle flow model



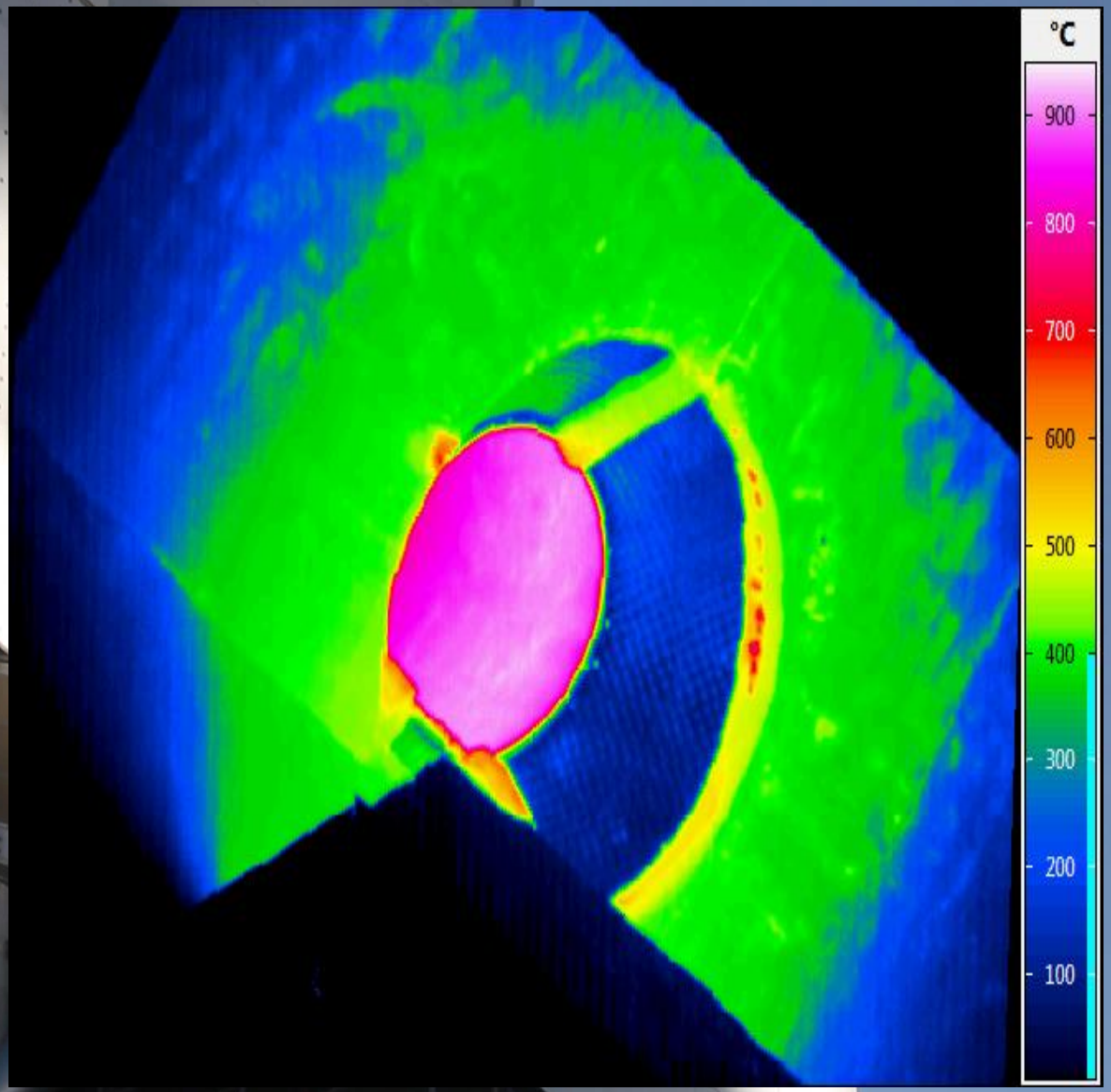
Results:
500 kW Receiver Design and Testing

Risk of “avalanches” avoided by design:

- Thin particle film regime (1-phase flow)
- Profiled wall surface structure
- Periodic modulation of rotation speed

Integration into Juelich Solar Tower: 05/2017

- Begin of solar testing: 24/09/2017
- Test campaign 2018 : 60 hours of solar operation
- Maximum particle exit temperature: 965°C


°C
900
800
700
600
500
400
300
200
100

Outlook

Particle Receiver Concept

- Industrial interest attracted:
  - Development of all critical components
  - 1MW_{th} complete system test starting 2020 @Juelich Solar Tower
  - Partner: German industry consortium and DLR spin-off company
- IEA SolarPACES: working group established to benchmark technology

- Longer term:
  Chemically active particles for thermochemical solar fuels production

Research Question 2

Is the concept fit to be operated for > 20 years in a desert environment?

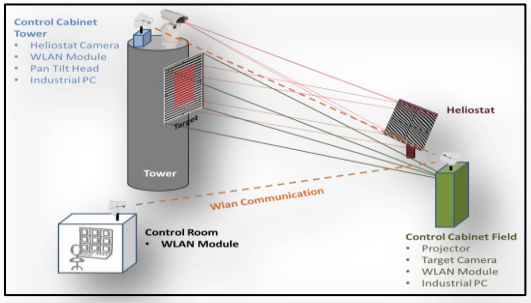
- Impact of aerosols on optical plant performance
- Quantification and comparison of different soiling effects on main components
- Comparison of dust properties and erosion rates at different desert locations

Infrastructure:
Dust & Aerosol Impact Lab @ PSA

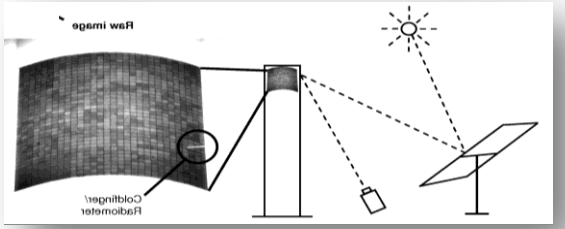
Research Question 3:

How to monitor the condition of a full solar plant with high accuracy?

- Heliostat characterization by automated deflectometry



- Flux density measurement wo/ target



- Cloud shadow monitoring

- **Use of UAVs in CSP systems**

Use of UAVs in CSP: DLR-QFly system

Separation of (i) **flight planning** (software)
(ii) data **acquisition** (UAV+hardware), and
(iii) data **processing and evaluation** (software)

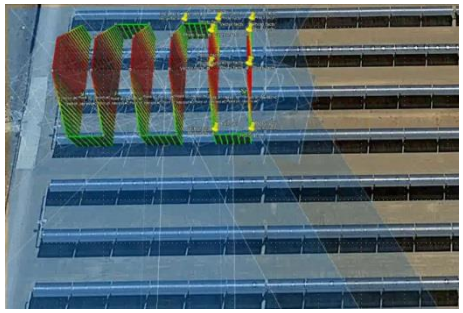
Hardware

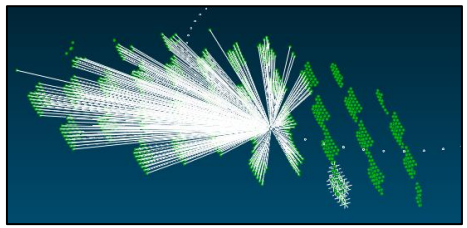
- UAV
  - MD4-1000
  - DJI Phantom 4

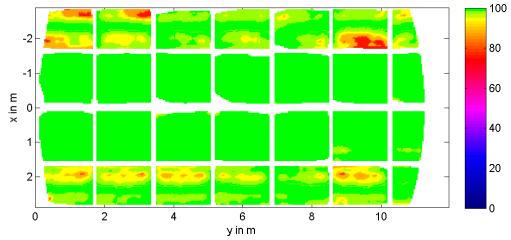
- PAYLOAD
  - Camera VIS
  - Camera IR
  - Gas sensor

Software:

- MATLAB
  - Waypoints
  - Image processing and evaluations
- AICON 3D Studio
  - Close-range photogrammetry
- SPRAY/STRAL
  - Ray-traycing



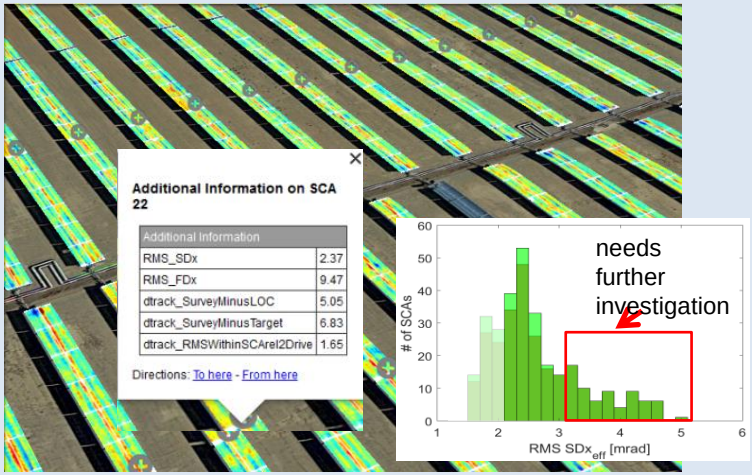




Validated tools in industrial environment

1 Parabolic Trough Shape Accuracy

- Shape deviation, absorber tube deviation, torrsion and tracking by defelctometry and photogrammetry
- Different flight modes depending on accuracy requierements
- 50 MW in 4 h flight time



2 *HCE Quality Screening*

- IR Camera on UAV
- Measurement accuracy ~2K
- Automatic location of receivers in solar field and reporting

Outlook: Tools under development

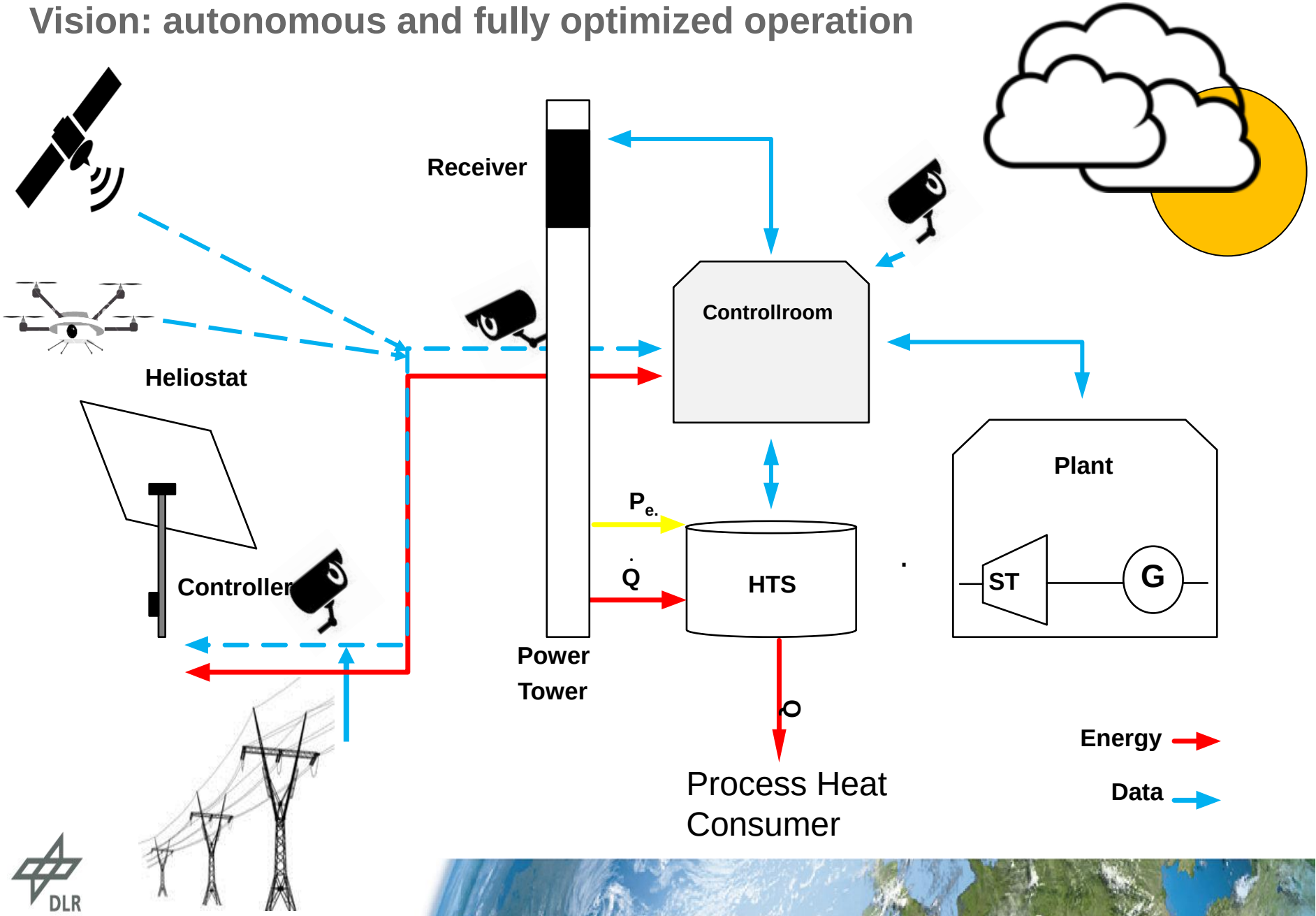
*HTF Sniffer for **Leakage Detection*** 4

- Promising experiments for **airborne detection/warning** of elevated concentrations of HTF products in air over solar field
- Currently **sensor integration**
- **Flights in power plant** in October

***Soiling / Cleanlines** Measurement* 5

- Promising proof-of-concept for airborne soiling measurement
- **Spatially resolved cleanliness maps**

Vision: autonomous and fully optimized operation



Thank you for your attention

Collaboration and Networks

Key International Research Partners

Ciemat

Sandia National Laboratories

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Networks

SolarPACES

Chairman, Secretary, 2 Operating Agents

ESTELA

Exco member

EERA European Energy Research Alliance

Sub Program Leader

DCSP German Association for Concentrated Solar Power

Board member

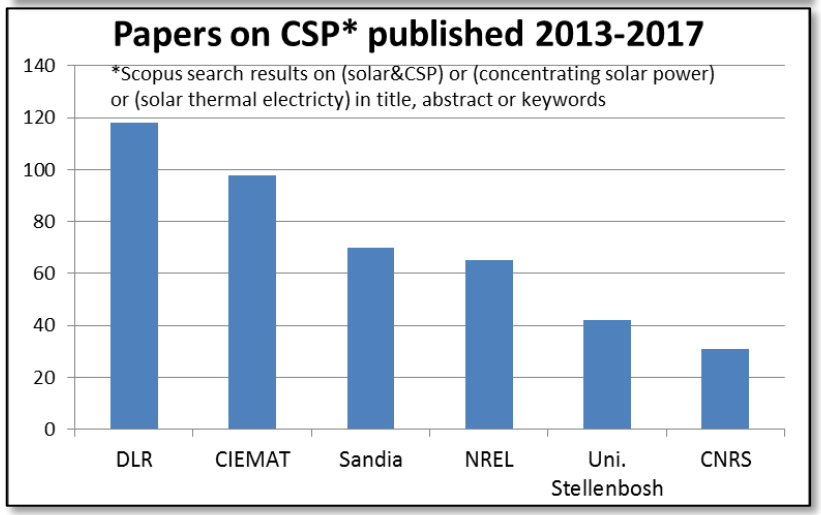
ISES International Solar Energy Society

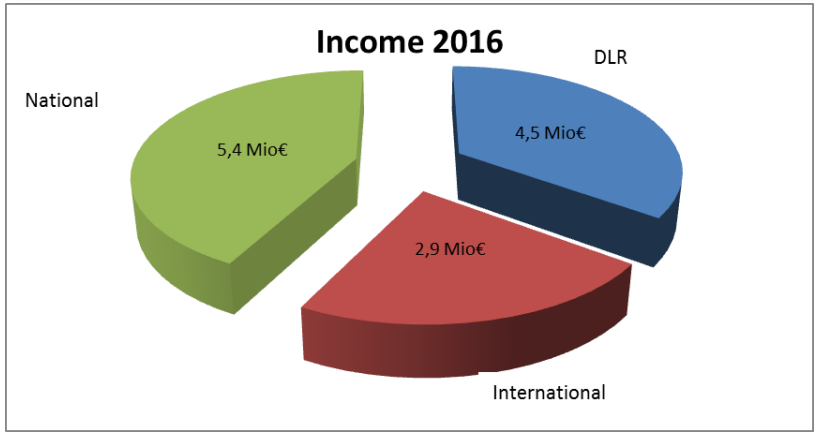
Farrington Daniels Award 2017

FORSCHUNGSNETZWERK ENERGIE FLEXIBLE ENERGIEUMWANDLUNG

Working group coordinator

- **11 scientific cooperation agreements**
- **36 industrial cooperation agreements**





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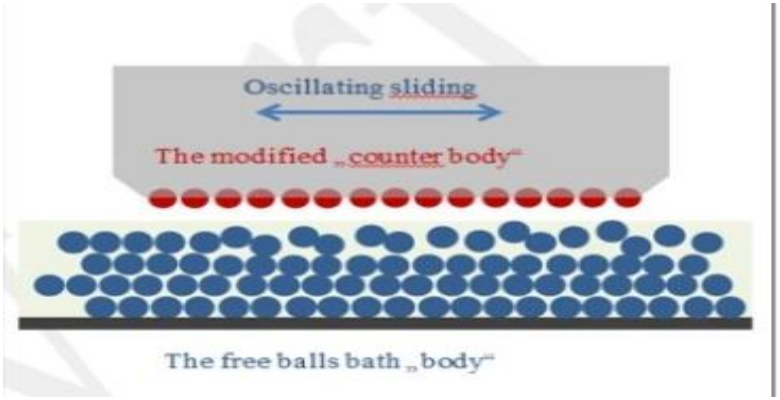
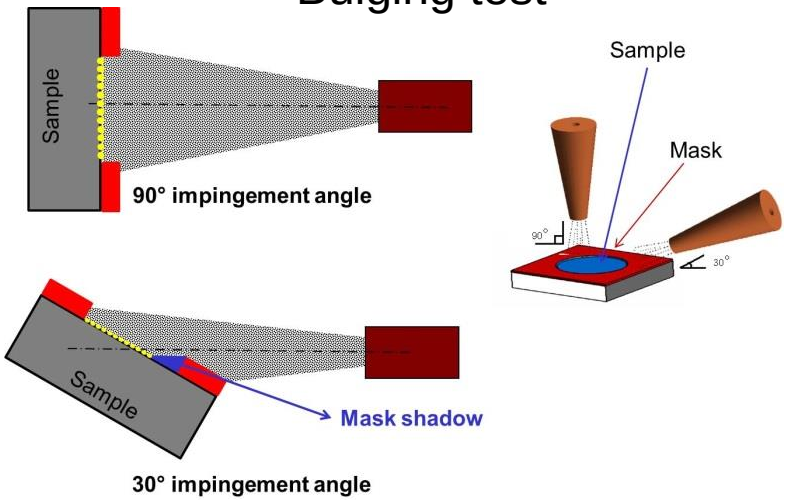
Abrasion of particle in rotating Receiver

Modifed Millertest
based on ASTM G75



Bulging test



.	mass loss [kg/MWh]	cost [€/MWh]
abrasion by Millner test	0,0571	0,04
abrasion by buiging test	0,378	0,28

In cooperation with SPE SOLIDS PROCESS ENGINEERING & PARTICLE TECHNOLOGY TUHH

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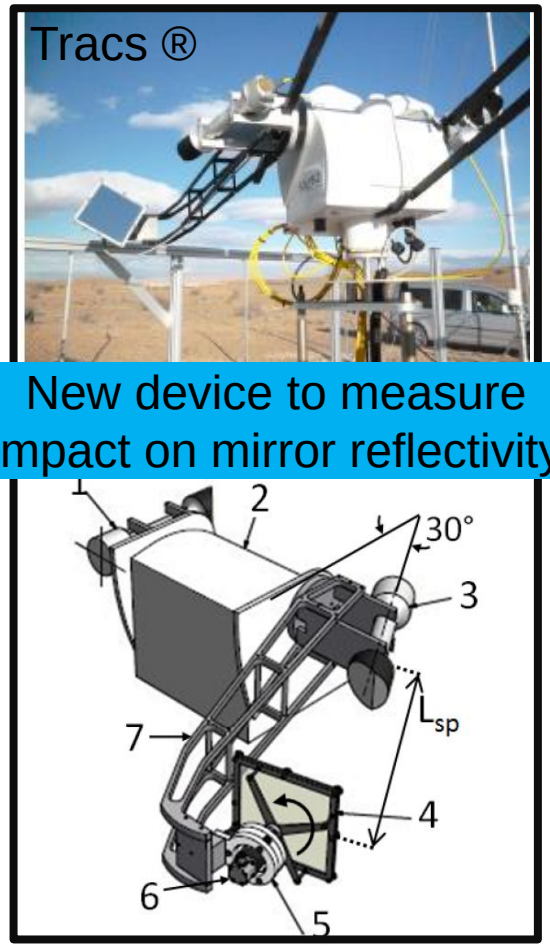
Impact of Desert Environment
Soiling

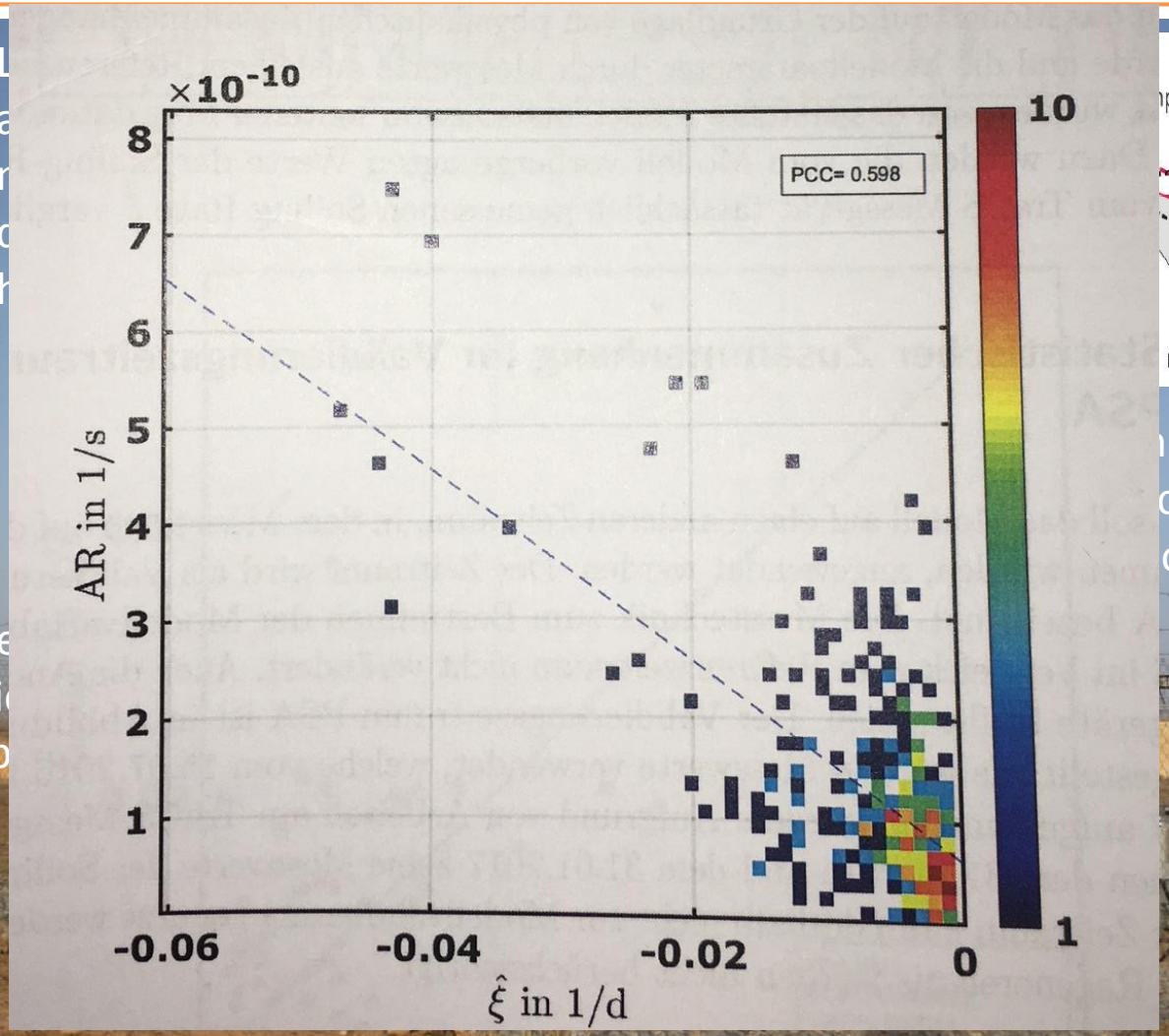
Soiling impacts optical efficiency

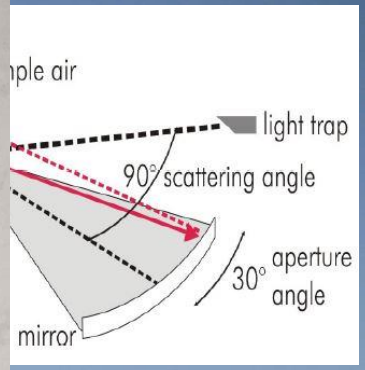


New device to measure impact on mirror reflectivity

Objectives

Remote measurement of Meteo Data at various sites in MENA





DustTrak

0.1-10µm

Filte
parti
samp

TSP

→ **Measurement data used to correlate particle deposition model**
Correlation significantly improved compared to previous approaches

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